RHIC Stochastic Cooling

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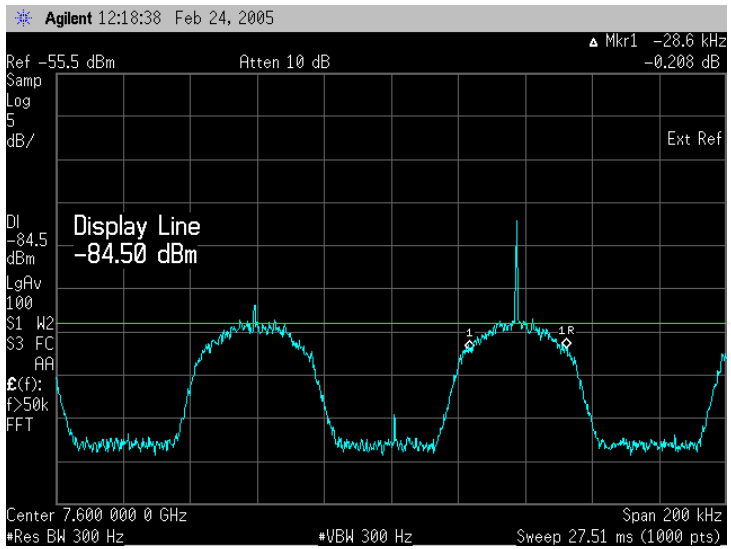
Motivation and Context

- IBS causes emittance growth which leads to debunching
  - Makes the collision vertex longer
  - Allows beam in abort gap
- Stochastic "cooling" can counteract IBS
  - S.c. was invented at CERN and *enabled* anti-proton colliders
  - The track record for extending s.c. to *bunched beam* was not good (abandoned at SppS and Tevatron)
  - Not part of RHIC base line design

Heavy ions should be different

- We (Mike Blaskiewicz) have been studying the Schottky signals in RHIC since day one
  - Heavy ions should be easier than protons
    1. Charge per ion, Z = 79
    2. Halo cooling
    3. Full bucket (dynamics similar to coasting beam)
    4. IBS actually helps (coherent components)
  - New technology (fiber optics)



Schottky spectrum of heavy ions at 7.6 GHz.
S/N is excellent, coherent lines are manageable

Principle (and limitations) of Stochastic Cooling

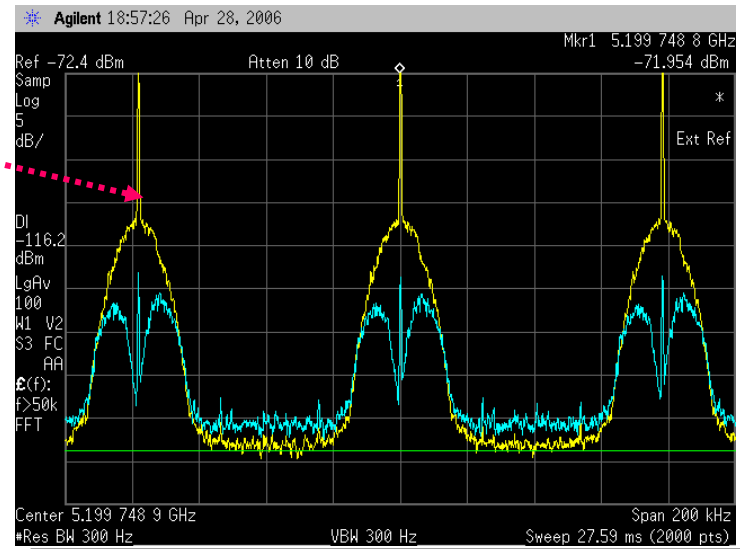
- Feedback and damp the fluctuations (energy or position)
  - You can measure the voltage (AC) from a resistor
    - Because the number of electrons is finite
    - Feedback on the fluctuations and cool the resistor
    - Beam fluctuations are the Schottky signal
    - A DC beam give a signal on and AC detector
  - Fewer ions make larger percentage fluctuations
- Basic equation of S.C.
  - Cannot cool protons, $N_{particles.}$
  - Need 8 GHz, **B**and**W**idth
  - Full bucket helps optimum gain
  - Cools "hot" beam best (halo cooling)

$$\tau_{cool} = \frac{1}{g_{opt}} \frac{N_{part.}}{BW}$$

Why is Bunched beam harder to cool than coasting (DC) beam?

1. The effective number of particles is amplified by the bunching factor
2. Coherent components in the Schottky spectrum challenge the dynamic range of the electronics
   1. High dynamic range, low noise amplifier
   2. New commercial fiber optic components
   3. Pre-filtering exploits bunched beam characteristics

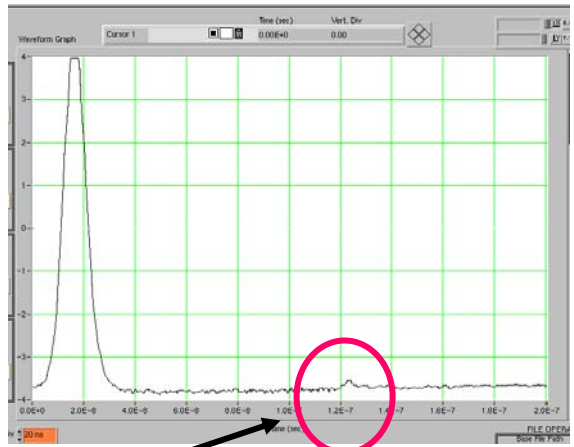
$$N_{effective} = \left(\frac{10^9}{5ns}\right) \times 12\mu s = 2.5 \times 10^{12}$$



Beam Spectrum at 5 GHz, with notch filter

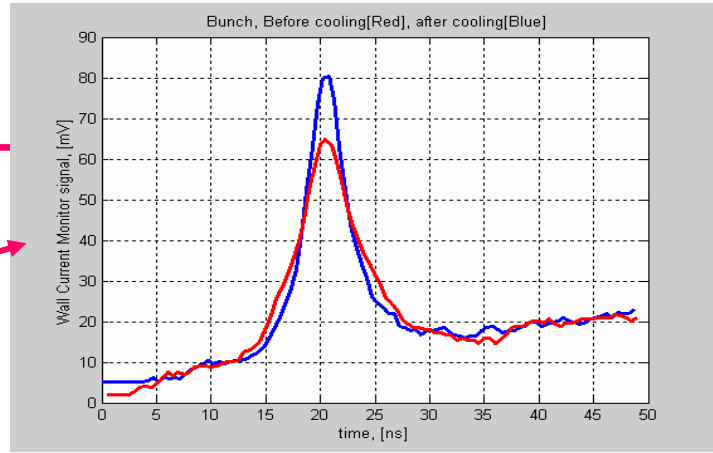
Recent Results

- In FY06 RHIC operated with protons only
  - $N_{part}=10^{11}$ per bunch > τ_{cool} = 100 hours
  - Of the 100 bunches in the store we took one
  - Reduced the intensity to 10^9 protons
  - Tested the cooling equipment in the Yellow ring on this bunch only

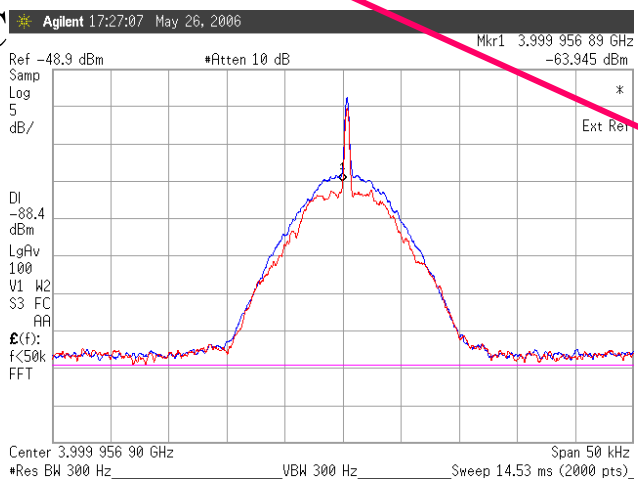


Results

- This is the first time stochastic cooling of a high frequency bunched beam has been observed
- Time domain (oscilloscope) and frequency domain (spectrum analyzer) measurements confirm cooling
- C

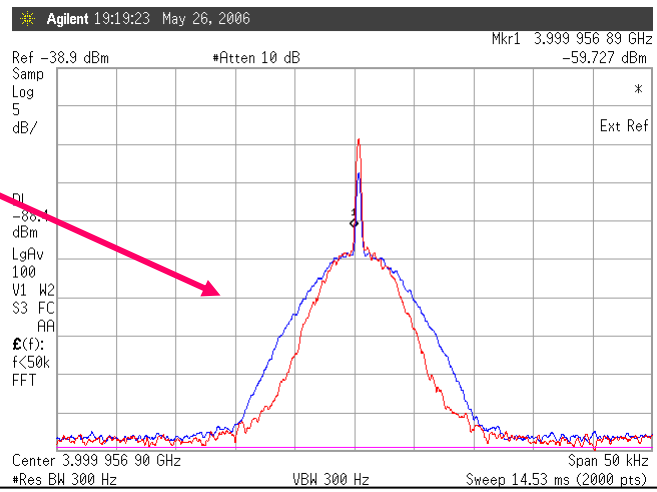


Bunch profile before (red) and after (blue) cooling, Wall Current Monitor



Schottky spectrum before cooling: blue trace

Signal suppression: red trace

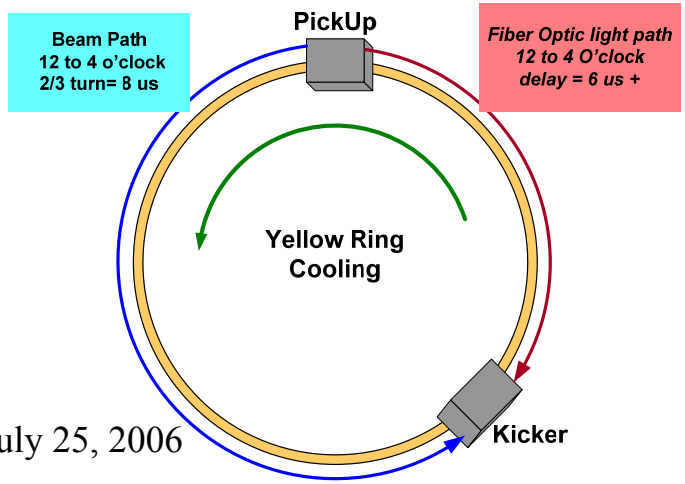


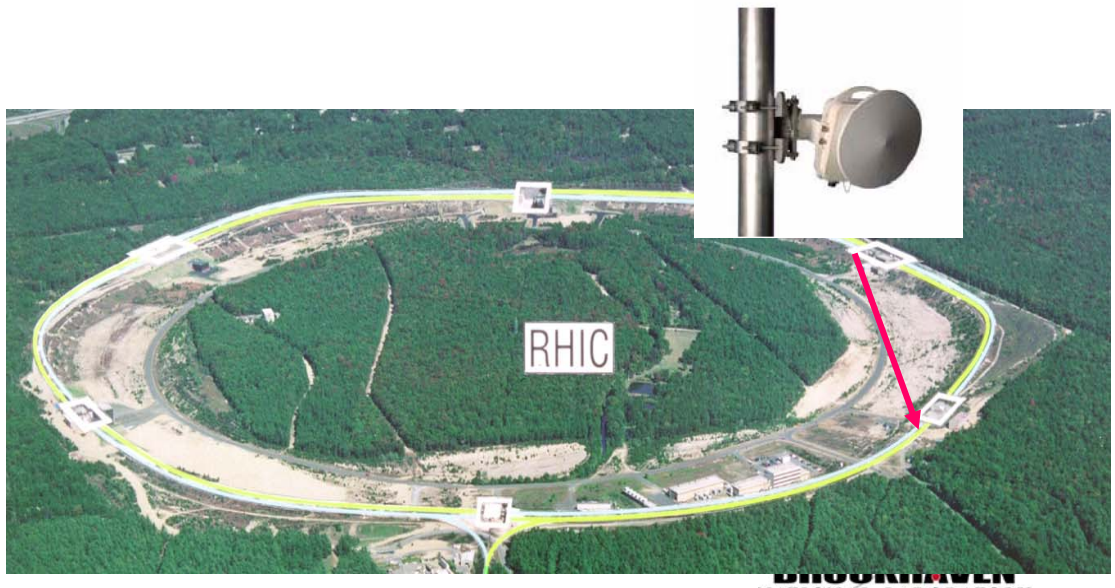
Schottky spectrum before cooling: blue trace

Spectrum after cooling: red trace

Plans

- In FY07 we will make the Yellow s.c. operational for gold beam
- For the Blue ring
  - Install pick up and upgraded kicker (water cooled)
  - Test “cutting the chord” with microwave link (70 GHz)
- After that comes cooling in the transverse planes
- Eventually s.c. will complement e-cooling by cooling the tails of the distribution





Extra slides

Stochastic Cooling Compared to E-cooling

- E-cooling can *reduce* the beam emittance
- Reduced emittance gives an order of magnitude more luminosity (RHIC II)
- E-cooling is not limited by particle number

- Stochastic cooling can prevent the emittance from *growing* (due to IBS)
- Counteracting IBS can extend the store lifetime and stop vertex growth
- Could yield x2 in integrated luminosity
- Stochastic cooling is limited to ~10^9 ions/bunch

The two systems complement one another

- Stochastic cooling cools "hot" beam best
  - Good for counteracting IBS
  - Effective for tails of distribution
- E-cooling cools "cold" beam best
  - Concentrates beam in a dense core
  - Leave tails, which can be addressed with stochastic cooling

1. Motivation and context (4)
    1. Stochastic cooling can counteract IBS
    2. Track record for s.c. is not good
    3. We have been studying s.c. for RHIC from the beginning of operations
        1. Heavy ions should be easier, charge/ion, halo cooling, IBS helps
        2. New technology, fiber optics

2. Principle of operation (5)
    1. Feedback on the fluctuations (voltage from a resistor)
    2. Higher bandwidth makes the number of particles lower (cooling equation)
        1. Why we cannot cool protons
        2. Why s.c. works best on "hot" beam
    3. Why bunched beam is harder
        1. Higher effective number of particles
        2. Coherent component in Schottky spectrum
        3. 100 GeV is an economic problem

3. Recent results (3)
    1. Test with 1e9 protons
    2. Demonstrated cooling

4. Plans (3)
    1. Make yellow operational for Gold FY07
    2. Study cutting the chord for Blue
    3. Long range (future AIP)
        1. Extend to transverse planes
        2. Complement eCooling by cooling tails ('hot")